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ABSTRACT

This phenomenological study took place over a 16-week semester during which 12 elementary school teachers explored mathematical ideas for elementary school students while using computer microworlds. Four themes were manifested in the case study of one teacher: learning on her own, authority and control, mathematics as manipulating, and frustration and confusion. The second case study brought forth the two themes of learning with others, and authority and control. The study demonstrates how the teachers' experiences can serve as a basis for a theoretical model for informing mathematics teacher educators about the multi-dimensional aspects of teachers' learning. (Contains 18 references.) (Author/AEF)

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Learning in the Context of a Mathematics Teacher Education Course: Two Case Studies of Elementary Teachers' Conceptions of Mathematics, Mathematics Teaching and Learning, and the Teaching of Mathematics with Technology

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Abstract: This phenomenological study took place over a 16-week semester during which 12 elementary school teachers explored mathematical ideas for elementary school students while using computer microworlds. Four themes of learning on her own, authority and control, mathematics as manipulating, and frustration and confusion were manifested in the case study of one teacher. The second case study brought forth the two themes of learning with others, and authority and control. The study demonstrates how the teachers' experiences can serve as a basis of a theoretical model for informing mathematics teacher educators about the multi-dimensional aspects of teachers' learning.

The purpose of this paper is to present some of the findings of a phenomenological study which described and interpreted the experiences of two female elementary school teachers as they understood and ascribed meaning to their conceptions (i.e., knowledge, beliefs, attitudes, and emotions) of mathematics as a discipline, the teaching and learning of mathematics in their classrooms, and the teaching of mathematics with technology in the context of a technology-enriched mathematics teacher education course. Whereas there is widespread agreement that teachers are key change agents to bringing about reform in the teaching and learning of mathematics including the teaching of mathematics with technology in their classrooms (Kaput, 1992; National Council of Teachers of Mathematics, 1991; Willis & Mehlinger, 1996), there is little research about the developmental process of teachers' learning in technology-enriched environments in order to facilitate the changes advocated in reform documents. This paper provides insight into how teachers' conceptions are formed and modified in the context of a mathematics teacher education course and facilitates informed decision-making concerning the infusion of technology into mathematics teacher education.

Addressing the problem of most teachers' lack of infusion of technology into reformed mathematics curricula and reformed teaching practices is important because many teachers who have not experienced mathematical learning in technology-enriched environments find it difficult to facilitate students' mathematical learning in such environments. According to the National Governors' Association (1991), "the most effective training is accomplished within the curricular area which the technology is to be used" (p. 37). Bull (1997) concurs that the "standards established by teachers and subject matter specialists in specific content areas may prove to be the most useful" for the integration of technology in teacher education programs (p. 338). A key issue that needs to be addressed for mathematics teacher educators or staff developers is how to design a professional development program which simultaneously challenges teachers' conceptions about mathematics, the teaching and learning of mathematics, and teaching of mathematics with technology, and provides opportunities for teachers to develop their confidence and competence in mathematical thinking and pedagogy while teaching with technology in their mathematics classes.

Theoretical Framework

Drawing on a blending of perspectives, I pulled together the intertwining strands of phenomenological, social constructivist, and affective perspectives which was based on an interaction between Confrey's (1991) potential integration of Piaget's and Vygotsky's theories of cognitive, intellectual development and McLeod's (1992) theoretical constructs of affective development, and a strengthening of the construct of attitude to include emotional intelligence; this resulted in a theoretical model that extended Myers' (1980) reciprocal

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model for interactions between learners' attitudes and behaviors. The phenomenon of this study is the teachers' perceptions of their learning which are based upon their interactions with the following: their own procedural and conceptual knowledge of mathematics, how to teach mathematics, how children learn mathematics, technology and teaching of mathematics with technology, the instructor and other teachers in the teacher education course, and non-human elements such as the computer microworlds.

Cobb (1994) calls for a coordination of constructivist and sociocultural perspectives in research about mathematics teaching and learning. Confrey (1992) discusses a new challenge for research concerning the role that technology plays in an individual's development of mathematical knowledge, and the viability of components taken from both Piagetian and Vygotskyian frameworks. Specifically, she raises the issue of "How ought we to view knowledge as it evolves in relation to our interactions with non-living objects and our interactions and interconnections with other human beings, and the interactions between these two types of interactions?" (Confrey, 1992, p. 44). It seems that both the types of interaction and the available tools of language and computers are crucial to a *co-shaping process* in which individual conceptions and social interactions contribute to cognitive development.

Important as the constructivist and sociocultural perspectives of teacher's learning might be, they seem to be incomplete. Using Mandler's cognitive approach to research on affect, McLeod (1992) proposes the reconceptualization of the affective domain in mathematics education to encompass not only attitudes but to include "beliefs, attitudes, and emotions as representing increasing levels of affective involvement, decreasing levels of cognitive involvement, increasing levels of intensity of response, and decreasing levels of response stability" (p. 579). Given the increased focus on high-level, conceptual understanding of mathematics recommended by current reform documents, a potential increase in the intensity of affective responses (e.g., emotions) to mathematics may result in promoting more positive or negative attitudes when compared to affective responses to mathematics while learning low-level, procedural understanding of mathematics. Within the context of the teaching of mathematics with technology, continued advancements in technological innovations may significantly change what mathematics is taught, and this may result in changing our beliefs about what is valuable in mathematics.

Participants and Data

Making the choice to participate in professional development courses for a reformed vision of the teaching and learning of mathematics that includes teaching mathematics with technology is accompanied often by a sense of anticipation. Some teachers have very little experience and expertise, and others have a great deal. Over the course of the semester, I studied the conceptions of three teachers, but for the purpose of this study I chose to focus on Robin and Susan. Robin's decision to enroll in this master's level mathematics teacher education course was motivated by her need for more "teacher training," her feelings of inadequacy towards understanding mathematics, and her desire to teach conceptually-oriented lessons involving manipulatives and mathematics software. At the time of the study, Robin was teaching a class of third graders for her second year in this school and had taught for seven years. Robin remembers experiencing the learning of mathematics as a subject that did not make sense to her as a child. Towards using technology, Robin describes that she likes working with computers (including the Internet) and learned to use them mostly on her own; she also enjoys spending many hours helping other people set up there computer systems.

Susan, the teacher in the second case study, explains that she enrolled in this course as part of her requirements for completing a master's degree in mathematics education. She describes the difficulty in finding courses that are "focused on the math and elementary together" and hopes for "a mix of ideas about theories of how kids learn and a set of practical, not lesson plans, but the idea of, what can I walk into my classroom and do." At the time of this course, Susan had taught for six years and was teaching a fourth-grade class for her second year in this school. She remembers testing out of the required mathematics courses for elementary education majors and she enjoys taking mathematics courses. When teaching with technology, she uses computers for students' drill and practice in mathematics, exploring patterns and problem solving with calculators, word processing, and e-mail connections to participants in the Alaskan Iditarod race.

The primary goal of the course centered on the teachers' exploration of mathematical knowledge within the domains of whole numbers and rational numbers through their use of *Tools for Interactive Mathematical Activity* [TIMA] (University of Georgia, 1994) computer microworlds and manipulatives. The *TIMA* microworlds developed from an analysis of the types of activities children employ in their construction of

number sequences and fraction schemes (Biddlecomb, 1994; Olive, 1993; Steffe & Olive, 1990). In the *Toys* microworld, *discrete* objects or toys can be replicated on the screen, connected, and counted as individual or composite units. Counting is a universal activity in which the learner constructs schemes relating objects to number. In the *Sticks* microworld, *continuous* objects or sticks are constructed on the screen, segmented, or iterated into composite units. Using the *Sticks* microworld, children use measuring strategies such as comparing, ordering, and quantifying in constructing knowledge about fractions. Given the research (Olive, 1993; Steffe & Olive, 1990; Tzur, 1995) on the role children-computer interactions and teacher-student interactions play in children's development of whole number and fraction knowledge, the study presented adapts these findings for examining teachers' knowledge of whole numbers and fractions.

As a participant observer, I recorded field notes for all graduate class sessions and videotaped each class, with one camera recording large group activities and the second focusing on the case study teachers. I conducted case studies of three of the teachers, including four audiotaped interviews with each teacher, collection of reflective journals and final projects, a series of nine classroom observations of the teachers in their classrooms, and pre- and post-course attitude surveys for all 12 teachers. Tapes (audio and video) were transcribed and analyzed. Data were collected and analyzed following the inductive process of *constant comparative analysis* described by Glaser and Strauss (1967). The analysis process consisted of identifying emerging themes and relating these to literature on elementary school mathematics teachers' learning, conceptions, technology, and teaching mathematics with technology, and developing assertions.

As part of a larger study, only a selected part of Robin's and Susan's conceptions of teaching mathematics with technology is presented in this paper.

The Experience

At the beginning of the study, both Robin and Susan described technology as machines or modern inventions that made peoples' lives "easier." They articulated that computer games were a fun way for students to practice basic mathematical skills. During the mathematics teacher education course, both women explored mathematical situations in which the *TIMA* microworlds were used regularly as tools to enhance their own and their students' mathematical learning. However, clear differences emerged in the teachers' experiences.

Doing mathematics with a computer is becoming involved with making sense of a partner's mathematical thinking through his or her actions and language while interacting with the computer; or, if working alone, only making sense of the learner's own thinking. Becoming familiar with mathematics while using a computer is about becoming part of both a community of mathematics learners and computer users who share values and expectations. For Robin, learning with a computer meant learning on your own and figuring things out by yourself. Characterizing herself as not being a "social learner," when Robin worked alone with the computer, she did not have to provide explanations for her actions or share her mathematical knowledge with others. In many instances, Robin's lack of conceptual knowledge of specific mathematical topics limited her ability to develop the language of mathematics and communicate her mathematical understandings of concepts to the other teachers. During our second interview, Robin struggled with her explanation about concept development and indicated she did not "know how to say these things."

Susan, on the other hand, explicitly articulated explanations about her conceptions of mathematics and specific mathematical topics, ways of learning to teach and how she taught mathematics, and how children learn mathematics. Already having some understanding of most of the mathematical concepts underlying the instructor's computer microworld tasks, Susan watched and joined in her partners' work, reflected and commented on their methods, and suggested alternative actions as they completed the tasks. Communicating mathematically was important for her own learning and that of her students; as Susan said, "So the things that were much more meaningful to me are the group work and the class, class-wide discussions." Consistent with Moreira and Noss' (1995) study, learning style influenced Susan's ability to construct an understanding of elementary mathematics topics and the teaching and learning of mathematics.

There remained a contradiction between Robin's enjoyment in figuring out knowledge related to *computer* actions by herself and her fear in figuring out knowledge related to *mathematical* actions and ideas. Unlike in Moreira and Noss' (1995) study, Robin's lack of confidence with mathematics and familiarity with computers did not develop into a "deeper confidence" with rethinking her knowledge about mathematics. When Robin talked about the mathematics of the computer tasks, she felt that the tasks were "very hard" and too "abstract" for her own understanding and that of her third graders. Such a situation can be interpreted as Robin disliking the computer tasks because she could not depend on the role visualizations played in her

understandings of mathematics (i.e., to transparently *show* her the mathematical concepts involved) to come up with an explanation on her own and talk about the mathematics. Still, significantly influenced by her interactions with the *TIMA* microworlds, Robin commented that the microworlds were a "good way" to make things a "little more abstract" than using manipulatives because the students could still see things on the computer screen but they couldn't touch them. She said, "Now they have to make a connection from something that they see in their brains and not with the touching." Because the objects of the microworlds helped Robin visualize a unit, she constructed and reflected upon her understandings of children's construction of number knowledge. For example, Robin defined the term *composite unit* by specifically using the *Toys* microworld to string and chain five shapes until 45 shapes appeared. When I asked Robin how the microworlds helped her understand children's mathematical learning, she talked of things making "sense" when she could actually see the connected units (e.g., strings and chains) and the separate, individual units (e.g., the single shapes). In using the visual representations of the microworlds, the context necessitated the development of a mathematical language in which Robin constructed a relationship between the actions and objects of the microworld, and mental schemes related to the mathematics embedded in the microworlds.

Robin's conceptions of teaching mathematics with technology remained relatively constant throughout the course. Teaching mathematics with technology meant using the overhead projector to demonstrate activities and problems with manipulatives during direct, whole-class instruction, or using computers for drill and practice and problem solving during individual instruction. Once Robin showed her students how to do the computer actions related to the software, she expected her students to work alone without any teacher intervention. In short, the computer took over as a more efficient and motivating teacher.

Working with a classroom set of calculators *fit* Susan's pedagogical approach to teaching mathematics: that is, she controlled and directed the activity of *all* students working on the same task at the same time. Susan valued and encouraged the development of a *mathematical discourse community* in which small-group and whole-group discussions focused on both Susan's and some of her students' mathematical thinking, strategies, and solutions. However, using computers in her classroom brought on feelings of questioning their value for her teaching of mathematics. In Susan's words,

> The computers though is where I feel unclear about. . . . Is there something that makes *TIMATOYS* a better tool then the fraction bar set or fraction factory. . . . I guess more the essence of my question is when is it appropriate to use that [*TIMA* microworlds] rather than just the blocks on the desks?

Shifting from a teacher-controlled, interactive teaching style of doing and talking about mathematics to a student-controlled, non-interactive teaching approach where students interacted with the computer and their partner did not make sense to Susan as an acceptable way to teach and learn mathematics. Even though Susan enjoyed the control over her own learning that she experienced while working with the other teachers and the *TIMA* microworlds, she became frustrated with having little, if any, control over or interaction with her students while they worked in pairs with the *Toys* microworlds. As Susan said, "I have no idea what they did. You know, I mean I was teaching the rest of the class. . . . So they all cycled through it, but I don't know what value it was." The introduction of microworlds on one computer into a mathematics classroom did not support an "all or nothing" interactive pedagogical approach towards learning mathematics.

Both Robin and Susan found the task of providing a meaningful conceptual explanation of *why* the invert-and-multiply algorithm works for the division of fractions to be a major conflict, or perturbation in their thinking. It is interesting, however, to contrast the two teachers' experiences. Robin openly expressed her feelings of being "terrified of math" and frustration with spending so much class time on the division task, whereas Susan enjoyed the challenge of the task and persistently went back and forth between the physical context of a scarves word problem (i.e., How many scarves can we make if it takes 2/5 of a yard to make one scarf and we have 3/4 of a yard of cloth?], the sticks model of the measurement interpretation of division within the *Sticks* microworld, and the symbolic language of mathematics to make sense of the problem situation. The processes of relating the actions and objects of the microworld to why the invert-and-multiply algorithm worked engaged Susan in challenging her thinking about the nature of fraction concepts and operations. Over the last five graduate class sessions, findings from the case study of Susan support one of Goleman's (1995) interpretations of emotional intelligence. By *motivating one's self*, Susan had the ability of focusing on an important goal (i.e., constructing a relationship between the *Sticks* microworld and why the invert-and-multiply algorithm works) during which she moved into a state of *flow* (i.e., high concentration) that facilitated her

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persistence in working on the task. Susan's work on this task engaged her in participating in "mathematical learning" that she described as forcing her "to think about really tough things."

As the study progressed, Susan's conceptions of teaching mathematics with technology changed somewhat. Drawing on her experiences in the graduate course, Susan changed the focus from teaching mathematics with *technology* to teaching mathematics with *tools* in order to think and talk about mathematics. Susan's experiences of learning and talking about mathematics while using the *TIMA* microworlds, listening to the ideas of the other teachers and the course instructor, and providing explanations about how "tools" (e.g., manipulatives, microworlds, etc.) enhanced her own and her students' mathematical learning strengthened her conception that technology makes things "easier." For example, the perturbation of the invert-and-multiply task afforded Susan with the opportunity to actually see *two* sticks rather than one stick being compared on the computer screen in order to reflect, think about, and talk about a fragile understanding of how different interpretations of division relate to why the invert-and-multiply algorithm works for the division of fractions. Moreover, this enabled Susan to *fit* her newly constructed ideas about *students* rather than the teacher deciding which manipulatives as tools would be useful in solving a mathematical problem, and still keep her interactive pedagogical approach of teaching mathematics. No longer did the construct of technology remain isolated as a separate entity. Even though Susan questioned the value of technology through the use of a one-computer classroom, she accepted the value and usefulness of teaching mathematics with tools that included not only computers, but manipulatives, calculators, rulers, and other resources found in elementary school classrooms. In short, technology began to lose its status as an *add-on* component when it became transformed into the more encompassing term of tools, and conformed to an existing interpretation of technology as a tool.

By the end of the course, both Robin and Susan did not use the *TIMA* microworlds in their teaching of mathematics. When teaching with the *TIMA* microworlds, Robin explained they could be used "to remediate certain concepts," but she became "overwhelmed" with the time it took to work with students individually and discontinued using the microworlds by the end of the study. In Susan's words, "I haven't figured out how to use one, with one computer what kind of activity I can have the kids go through without me there sitting by their side to direct it." However, Susan's statement persisted as a contradiction to her conceptions of students being able to learn mathematics with microworlds because Susan believed that students "created" the mathematics, took control and tried out their ideas, and developed "their own concepts about it along the way."

Discussion of Findings: Conditions for Teachers' Learning

As part of a larger study, two assertions that can be made are: 1) Change in mathematics teaching warrants change in teacher's conceptions of mathematics and learning. Robin's experiences in the graduate course did not transform her into becoming a learner of mathematics, and she did not construct an understanding as to *why* improving her own learning of mathematics could facilitate her teaching of the mathematical concepts and skills contained within the third-grade curriculum, or her teaching of mathematics with technology; and 2) Personal learning preferences and styles influence the process of teachers' learning in technology-enriched environments. Susan's positive experiences of constructing relationships between multiple representations of mathematics and articulating the language of mathematics by providing explanation to others contributed to her ability to discuss and make explicit the mathematical ideas that she already knew related to the computer tasks, and to crave the intellectual challenge of rethinking mathematical ideas at a higher level of understanding. Consequently, mathematics teacher educators need to challenge teachers' conceptions at the *teachers'* levels of mathematical understanding and abilities to express mathematical ideas by providing opportunities of scaffolding in tasks and ensure adequate levels of internal and external support for teachers' development as learners of mathematics; mathematics teacher educators need to provide a variety of classroom organizational styles when teaching mathematics with technology to recognize the fact that differences in teachers-as-learners learning styles and differences in tasks oblige a variety of environments for learning; awareness of the role emotional intelligence plays in enhancing or blocking teachers' control over their learning; without the provision of technology-enriched innovative curriculum materials, teachers may not engage in teaching mathematics with technology through the use of computer microworlds; and, teachers can develop ways to communicate mathematically and contribute to their shared understandings through the words, objects, and actions represented in the microworlds, as well as make their conceptions of mathematics and mathematics teaching and learning explicit for themselves and others.

Collectively, these findings suggest that the experiences of elementary school teachers in the context of a technology-enriched mathematics teacher education course serve as a basis of a theoretical model for

informing teachers' learning of mathematics, mathematics teaching and learning, and the teaching of mathematics with technology. The model can serve mathematics teacher educators, educational technology educators, teachers-as-learners, and researchers by focusing their attention on the multi-dimensional aspects of conceptions (i.e., knowledge, beliefs, attitudes, and emotions) on teachers' learning by coordinating analyses of individual and group interactions from experiences with humans and non-human objects in an attempt to understand and make meaning of the social constructivist and affective components of teachers' learning.

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